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FEASIBILITY OF SAND BYPASSING SYSTEMS FOR REDUCING MAINTENANCE DREDGING IN THE ST. MARYS RIVER ENTRANCE CHANNEL

by

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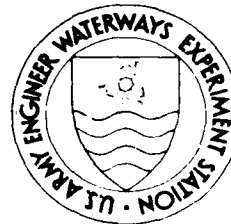
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Preface

In September 1984, the US Army Engineer Waterways Experiment Station (WES) was requested by the US Navy, Officer in Charge of Construction, Trident, and the Strategic Systems Program Office, to perform a feasibility study of the use of sand bypassing systems for reducing maintenance dredging requirements in the St. Marys River entrance channel that provides access to the Trident Submarine Base in Kings Bay, Georgia.

The study was conducted by Messrs. D. R. Richards of the Hydraulics Laboratory (HL) and J. E. Clausner of the Coastal Engineering Research Center (CERC), WES. Dr. R. E. Jensen of CERC performed longshore transport potential calculations that were used in the study. Supervision and assistance in the study were provided by Messrs. W. H. McAnally, Chief of the Estuaries Division; HL; E. C. McNair, Estuaries Division; and T. W. Richardson, Chief of the Coastal Structures and Evaluation Branch, CERC. This report was prepared by Messrs. Richards and Clausner.

COL Dwayne G. Lee, EN, is the Commander and Director of WES.
Dr. Robert W. Whalin is the Technical Director.

Contents

	<u>Page</u>
Preface.....	1
Conversion Factors, Non-SI to SI (Metric) Units of Measurement.....	3
Introduction.....	4
Sand Bypassing Systems.....	4
St. Marys River Entrance.....	5
Data Summary.....	11
Feasible Systems.....	13
Conclusions.....	16
References.....	17

Conversion Factors, Non-SI to SI (Metric)
Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	25.4	millimetres
miles (US statute)	1.609344	kilometres
miles (US nautical)	1.852	kilometres

FEASIBILITY OF SAND BYPASSING SYSTEMS FOR
REDUCING MAINTENANCE DREDGING IN THE
ST. MARYS RIVER ENTRANCE CHANNEL

Introduction

1. The US Navy is currently involved in expanding its submarine base in Kings Bay, Georgia, to allow complete support facilities for the Navy's new fleet of Trident submarines. In doing so, major improvements to the navigation channels will be required to accommodate the larger and deeper draft vessels. The improvements include extensive channel deepening, realignments, and possibly the construction of structures to assist in minimizing increased maintenance dredging requirements.

2. The US Army Engineer Waterways Experiment Station (WES) was requested by the Navy to provide guidance on predicting changes in the hydrodynamic and sedimentation characteristics throughout the Kings Bay area that would result from the channel improvements. The approach taken by WES includes using physical and numerical models to make these projections both inside and outside the St. Marys River entrance.

3. In a separate request, the Navy asked WES to evaluate the use of sand bypassing systems as a means of minimizing shoaling and the required maintenance dredging in the St. Marys River entrance channel. The purpose of this report is to give the findings on the feasibility of sand bypassing at the St. Marys River entrance.

Sand Bypassing Systems

4. Sand bypassing is a dredging technique that is used to promote the transfer of sand around barriers which interfere with the natural processes of longshore transport. It is typically used at coastal inlets where man-made jetties provide obstructions that result in entrance channel shoaling and erosion of downdrift beaches. Bypassing is most commonly accomplished by using dredge pumps and pipelines to provide the means of transportation for the sand. A wide variety of system configurations are possible and are generally designed to address site-specific requirements.

5. Sand bypassing systems are normally classified by their degree of mobility (Richardson and McNair 1981). They can be classified as follows:

- a. Fixed systems. These systems have their entire physical plant fixed in a single location. Common examples include dredge pumping systems that operate from a pump house or jet pump systems using fixed jet locations. These systems are effective only if the flow paths of the littoral transport are predictable and the bypassing intakes can be located properly.
- b. Mobile systems. The entire physical plant of mobile systems can be easily relocated throughout the project area depending on the location of the material to be bypassed. Typical examples include floating dredges or movable jet pump arrays. An advantage of mobile systems is that they can be moved to the areas of most concern which can vary considerably depending on the season or on particular storm events.
- c. Semimobile systems. These systems as the name implies incorporate features from both fixed and mobile systems. They are mobile in the sense that they have limited mobility within a given area of the project site. They are fixed in the sense that they cannot be moved to all areas of the project site. An example would be dredge pump or jet pump systems that are attached to a portion of a jetty and can move along the jetty by the use of a railway.

6. The feasibility of bypassing at a particular inlet is controlled by the coastal processes in and around the inlet. Of major importance is the amount of sand to be bypassed (which is normally equal to the net longshore transport rate), the direction in which to bypass (downdrift or updrift), and the frequency at which bypassing needs to be conducted (continuous or intermittent).

St. Marys River Entrance

7. The St. Marys River forms the boundary between the States of Georgia and Florida (Figure 1). The river's entrance on the Atlantic Ocean is protected by rock jetties on the north and south sides. At high tide the jetties are completely awash and provide little protection in severe storms. Of more importance to this study, however, is the fact that the jetties are permeable and allow significant quantities of sand to pass through and into the navigation channel. Once sand finds its way into the channel, tidal currents transport it into the offshore bar or into the flood tidal delta in the interior bay. The inlet itself is currently near a state of dynamic

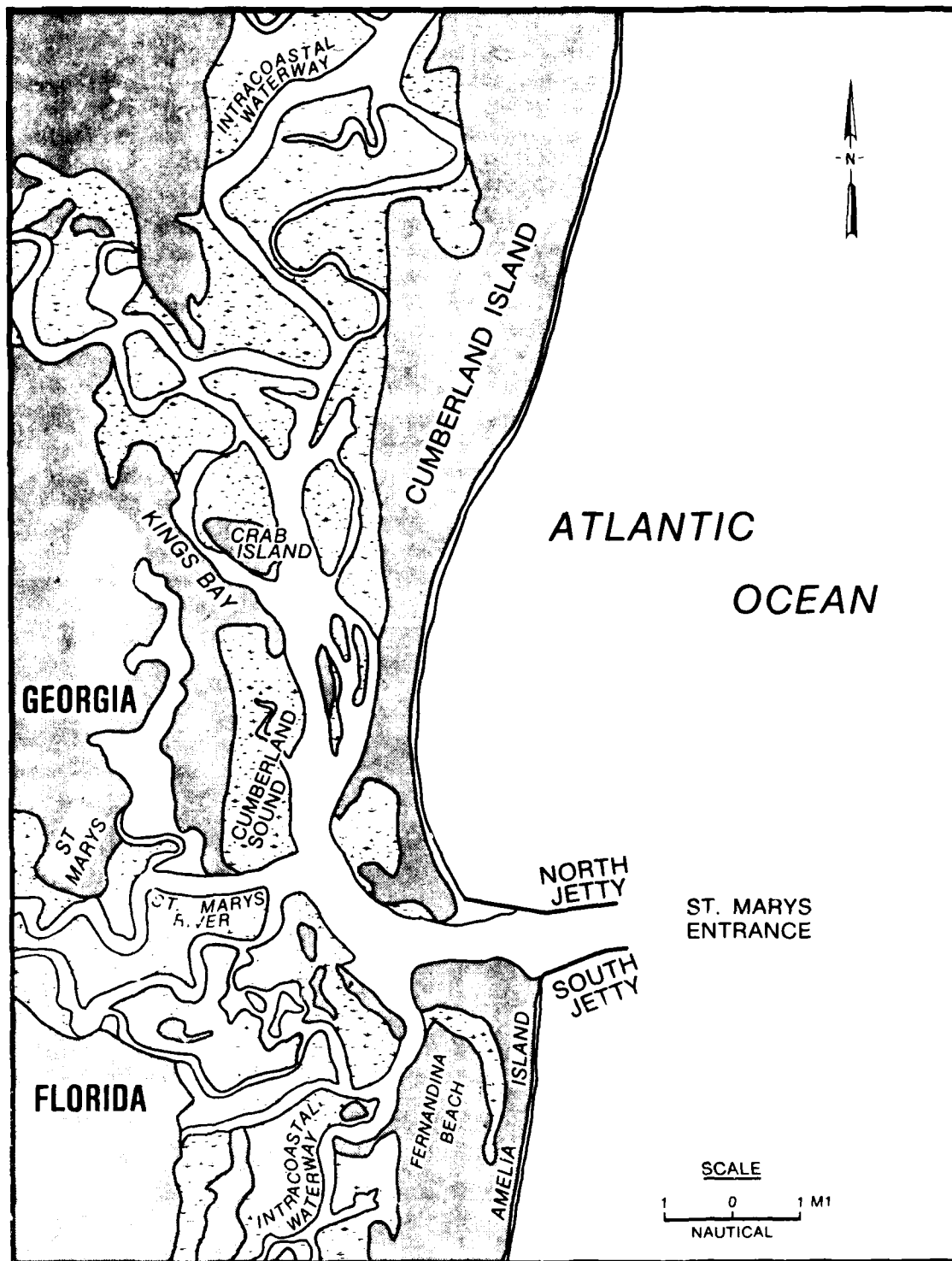


Figure 1. Vicinity map

equilibrium and shows little evidence of changing its geometry despite the condition of the jetties. There do, however, appear to be significant quantities of sand deposited in the offshore bar and in the entrance channel leadings to Kings Bay. Extensive dredging will be required in the future to keep the bar channel passable to deep-draft vessels, so an effort to minimize the amount of dredging needed is desired. To achieve that end, sand bypassing is being considered.

8. An effective evaluation of sand bypassing at any location requires a thorough knowledge of the sediment transport regime. Estimates of sediment transport for St. Marys Entrance and the adjacent areas were collected from available sources and are summarized in Table 1.

Table 1
Yearly Sediment Transport Rate at St. Marys
Entrance and Vicinity (1,000 cu yd)

<u>Source</u>	<u>South</u>	<u>North</u>	<u>Net</u>	<u>Gross</u>
COE* dredging records St. Johns River	600	100	500 S	700
University of Florida	380	142	238 S	522
Florida Coastal Engineers	500+	500	?	1000+
CERC,** hindcast data, Little Cumberland Is.	700	335	365 S	1035
CERC, hindcast data, St. Marys Entrance	544	454	90 S	1008
CERC, hindcast data, Fernandina Beach	503	547	44 N	1050
CERC, LEO† data, Atlantic Beach	321	234	87 S	551

* US Army Corps of Engineers.

** Coastal Engineering Research Center.

† Littoral Environmental Observations.

9. Estimates from the Corps of Engineers dredging records (CSAED, Jacksonville, 1976) provide the only data that are actually based on physical measurement. These data, however, are for a site 21 miles south of the St. Marys Entrance. The same report contained estimates by the University of Florida but no documentation on how the figures were calculated.

10. The estimate from Florida Coastal Engineers contains the most information of any of our estimates. This firm produced a contract report to the Jacksonville District on beach erosion on Amelia Island. Based on volumetric calculations of the St. Marys Entrance and surrounding bathymetry over a 94-year period from 1881 to 1975, it was concluded that the construction of the jetties in 1881 to 1904 drastically changed the inlet hydraulics. Since the jetties are permeable to sand, they concluded that the inlet functions as a complete littoral trap. It was also stated that refraction effects from the large offshore bar east of the jetties cause waves to refract toward the inlet from virtually all directions. Fillets formed south of the south jetty and north of the north jetty seem to support this conclusion. Based on the volume changes seen in the area, formation of the offshore bar, and loss of sediment from the nearshore region and between the jetties, Florida Coastal Engineers estimated the average gross sediment transport to be approximately 1,000,000 cu yd/year over the last 100 years. In addition, they estimated that changes in the inlet have effected coastal processes for a distance of 16 miles, 8.5 to the north and 7.5 to the south.

11. During the course of this study, WES calculated longshore transport potential at three 10-nautical-mile-wide grid cells--Little Cumberland Island, St. Marys Entrance, and Fernandina Beach (Figure 2). The calculations were based on Phase III Wave Information Study (WIS) data (Jensen 1983) using the 1977 Shore Protection Manual (SPM) (CERC 1977) transport equations. The WIS wave data were calculated from meteorological data collected from 1956 to 1975. Pressure data at three-hour intervals were translated into pressure fields, which were used to generate surface winds. The wind was used as input to a numerical model to simulate wave generation, propagation, and decay. Transport potential was then calculated on a monthly basis from 1956 to 1975. Deepwater wave information was refracted into the 10-m contour, and then carried into shore with the calculated refraction angle assuming straight and parallel depth contours. The data calculated by the program are based on the average conditions within the 10-nautical-mile-wide grid cell. Consequently,

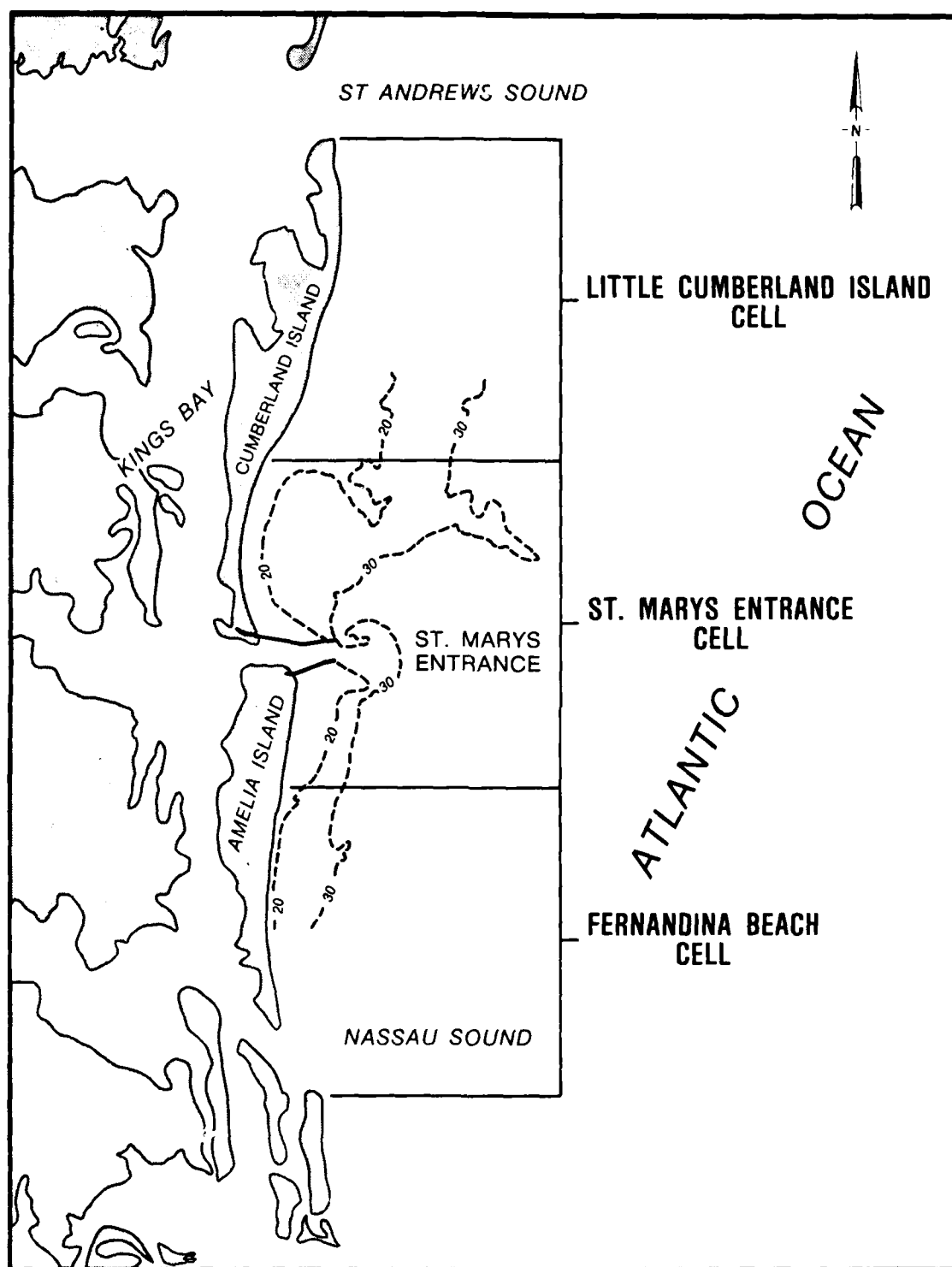


Figure 2. Map showing locations of WIS cells and offshore bathymetry

the local effects of the jetties and offshore bar are not reflected in the data. The Little Cumberland Island cell (30.98N to 30.81N) is centered 10.8 nautical miles north of St. Marys entrance. The St. Marys Entrance cell (30.81N to 30.64N) is centered 0.7 nautical mile north of the inlet. The Fernandina Beach cell (30.64N to 30.48N) is centered 9.3 miles south of the inlet. The numbers presented in Table 1 are the 20-year averages for the St. Marys entrance cell. As might be expected, yearly and monthly data vary widely from the average values.

12. Yearly net transport potential values for the St. Marys entrance cell are presented in Table 2. They ranged from 630,000 cu yd to the south to

Table 2
Yearly Sediment Transport Values
for WIS St. Marys Cell

<u>Year</u>	<u>North</u> <u>1,000 cu yd</u>	<u>South</u> <u>1,000 cu yd</u>	<u>Net</u> <u>1,000 cu yd</u>	<u>Gross</u> <u>1,000 cu yd</u>
1956	260	520	260 S	780
1957	514	487	27 N	1,000
1958	502	596	96 S	1,100
1959	675	925	250 S	1,600
1960	542	558	16 S	1,100
1961	575	524	49 N	1,100
1962	510	450	60 N	960
1963	435	1,065	630 S	1,500
1964	750	651	99 N	1,400
1965	405	535	130 S	940
1966	520	680	160 S	1,200
1967	215	515	300 S	730
1968	247	224	23 N	470
1969	583	617	34 S	1,200
1970	457	363	94 N	820
1971	405	535	130 S	940
1972	440	760	320 S	1,200
1973	498	493	5 N	990
1974	329	361	32 S	690
1975	330	120	210 N	450

210,000 cu yd to the north. The average net transport potential was 15 percent of the gross transport. Gross values ranged from a low of 450,000 cu yd to a high of 1,600,000 cu yd. Monthly averages, standard deviations, and maximum values of sediment transport potential for the St. Marys entrance cell are presented in Table 3. Data from the adjacent two cells have similar

Table 3
Monthly Net Sediment Transport Values
for St. Marys Entrance

<u>Month</u>	<u>Avg Net Sediment Transport 1,000 cu yd</u>	<u>Standard Deviation 1,000 cu yd</u>	<u>Max Net Sediment Transport 1,000 cu yd</u>
January	25 S	33	95 S
February	12 N	51	140 S
March	25 N	40	110 N
April	31 N	32	110 N
May	9 N	29	63 N
June	12 N	31	100 N
July	10 N	12	39 N
August	0.4 S	13	29 S
September	43 S	75	250 S
October	80 S	84	240 S
November	32 S	55	160 S
December	13 S	61	160 S

ranges. In an average year, southerly transport occurs from September through January, while northerly transport takes place from February through July. The large standard deviations show the tremendous amount of variability in the monthly data. In fact, the standard deviations are larger than the average in every month. Data from the little Cumberland Island cell and the Fernandina Beach cell have similar amounts of variability in the monthly values.

13. The CERC transport potential estimate at Atlantic Beach, 26 miles south of St. Marys Entrance, is based on Littoral Environmental Observations (LEO) from 1978 to 1981 (Walton 1980; Schneider 1981). Sediment transport calculations were made using equations from the 1984 SPM. Unfortunately, the quality of observations was not good, nor were the records complete; however, the data are within the range of the other estimates. Monthly variations in the sediment transport values were similar to the hindcast data, with a majority of the southerly transport occurring in the fall and early winter and the northerly transport occurring in the spring and summer.

Data Summary

14. Reviewing the above results, longshore sediment transport in the

vicinity of St. Marys Entrance may be best estimated at present by WIS hind-cast results. The 20-year average gross transport rates from those calculations can account for the tremendous amount of sand moved offshore as documented by Florida Coastal Engineers. Bathymetric changes showed that approximately 100,000,000 cu yd have moved from the nearshore zone in and around St. Marys Entrance to the offshore bar in the past 100 years, an average of 1,000,000 cu yd/year. The WIS potential longshore transport rate agrees very well with the actual changes that occurred. Also, based on bathymetric changes, Florida Coastal Engineers predicted southerly transport to be slightly higher than northerly transport. The WIS data support this conclusion, with an average net transport value of 90,000 cu yd/year to the south.

15. Although the variations in monthly transport make precise transport values difficult to define, it appears that offshore bathymetry may produce a nodal point for sediment transport at St. Marys Entrance. The large gross transport (1 million cu yd) with little net drift (90,000 cu yd to the south) continues to provide a large amount of sand to the inlet. Porous jetties and tidal flow through the entrance combine to form an efficient means of moving the sand into the inlet and out onto the offshore bar. Local wave transformation effects from the jetties and offshore bar may increase the efficiency of this process by producing transport toward St. Marys Entrance from most any wave direction. The Jacksonville District estimates that the wave transformation effects extend up to 4 miles south of the jetties, with the majority of the effects occurring in the first mile. No estimate was made by the Jacksonville District of effects to the north, but it is reasonable to assume that the distance is similar.

16. Considering all of the longshore sediment transport estimates, it seems reasonable to proceed with the following assumptions for sand bypassing requirements for the St. Marys Entrance:

- a. The average net yearly transport rate over the 10-nautical-mile reach that includes St. Marys Entrance is approximately 90,000 cu yd per year to the south.
- b. The average yearly gross transport rate or the amount of material that is available for deposition in the entrance channel is approximately 1,000,000 cu yd per year.
- c. The average yearly maintenance dredging volume in the entrance and offshore channel is 475,000 cu yd/year at present and predicted (Vemulakonda et al. 1988) to be 780,000 cu yd/year for the Trident Channel.

Feasible Systems

17. Normally, sand bypassing systems are used to reduce the amount of maintenance dredging required in inlets that have a significant net longshore transport. The systems are ordinarily designed to bypass the net longshore transport to the downdrift beach. In doing so, the required maintenance dredging of the entrance channel will be diminished by this net amount. To the extent that the net transport comprises a large portion of the gross transport, bypassing can be extremely feasible and can provide significant cost savings. With regard to the St. Marys entrance, the net transport of 90,000 cu yd/year to the south is a small portion of the gross transport of 1,000,000 cu yd/year. Sand bypassing, in the unlikely event that it would be totally effective, would remove less than 10 percent of the gross transport. It does not appear that bypassing the net littoral transport of 90,000 cu yd/year will significantly reduce maintenance dredging requirements in the entrance channel. Therefore, sand bypassing for the specific purpose of reducing maintenance dredging volumes in the entrance channel does not appear to be feasible.

18. Sand bypassing may be considered feasible based on other considerations and more limited expectations. There is a possibility that beaches in the city of Fernandina Beach would be improved by bypassing sand from the shoal just south of the north jetty (Figure 3). According to the Jacksonville District, this shoal is gradually accreting over time and the removal of sand in a bypassing operation would not adversely affect the structural integrity of the north jetty. The bypassed material could easily be transferred without disrupting navigation by pumping it through a pipeline placed under the channel. The discharge point should be at least 2 miles south of the south jetty to minimize the amount of sand moved to the north by local wave effects. The most effective time to conduct the bypassing from a coastal processes standpoint would be during August. The fall and winter waves will then move the bypassed sand to the south providing nourishment to the eroded beaches on Amelia Island.

19. Sand bypassing from the interior shoal to the beaches of Amelia Island may offer benefits to the Navy and to the beaches of Amelia Island. Since maintenance dredging will be required periodically in the entrance channel and the interior shoal, this material will have to be disposed of in

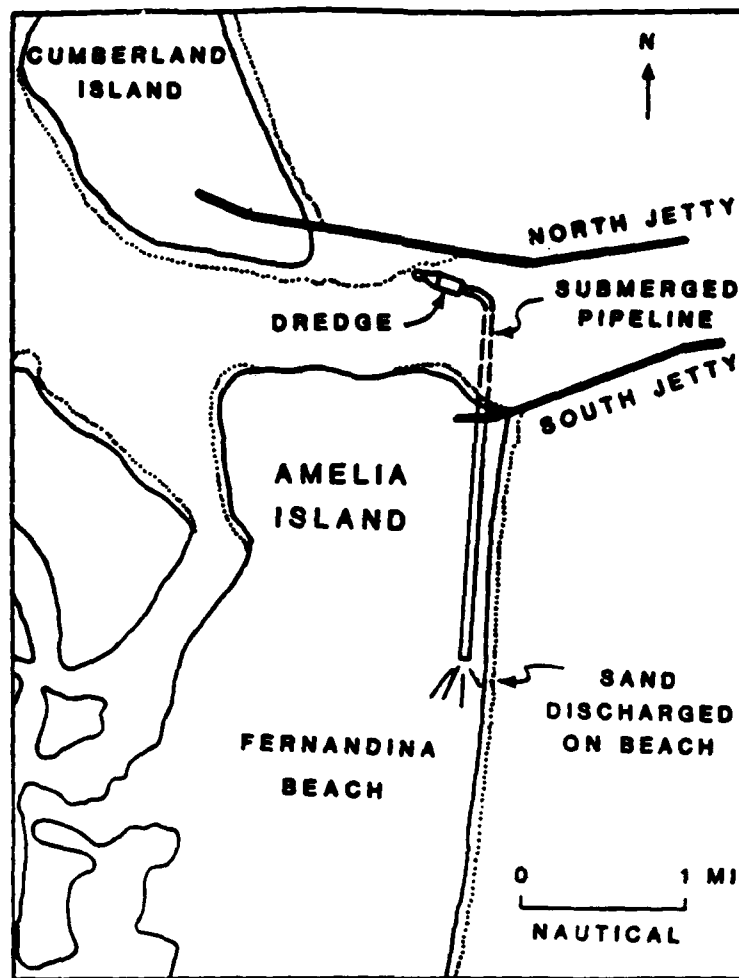


Figure 3. Schematic of dredge bypassing sand from the interior shoal

either a confined disposal area of which there is limited capacity in Kings Bay or in open water which requires expensive transportation costs. Based on disposal problems alone, this manner of bypassing may be feasible. Another benefit of bypassing in this way involves the economics of dredging. Large quantities of material can be moved in a short period more easily in protected waters. It may be more economical to contract a large cutterhead dredge (larger than 18 in.) to dredge the material in protected waters before it is transported offshore where more expensive hopper dredges may be required. The cutterhead dredge could come in once a year during the month of August and pump at a high production rate for a relatively short period of time. Dredging the interior shoal would be easy digging and the jetties would provide the required wave protection for the dredge. By dredging just the top 3.7 ft from

the 1,450- by 5,100-ft shoal, as much as 500,000 cu yd could be removed and transported to Fernandina Beach. This would provide a substantial amount of nourishment initially and smaller amounts could be bypassed thereafter depending on the needs of the beaches and disposal requirements from maintaining the entrance channel.

20. Another option in the above scenario is using cutterhead dredges that may already be performing maintenance work in the upper Kings Bay to do the bypassing by temporarily suspending operations during the month of August and then returning to complete Kings Bay after the bypassing has been completed. In this way, mobilization and demobilization costs could be minimized compared to setting up a separate contract to do bypassing with perhaps a different contractor.

21. Cutterheads are not the only type of mobile system that could be feasible. Hopper dredges have been used to maintain the entrance channel and could be used in a bypassing scenario. In fact, the Corps of Engineers hopper dredge, Comber, was used in 1982 to provide nourishment to Fernandina Beach. After filling its hoppers, the dredge tied up to mooring barges and pumped the sand through a submerged pipeline to Fernandina Beach. Bypassing could be accomplished using hopper dredges in this type of application; however, an economic comparison could show cutterhead dredges to be more economical. A choice between these two types of dredges should be based on economics and availability rather than the intrinsic properties of the dredge types.

22. Other types of bypassing systems were considered but none showed the promise of the entirely mobile systems. Fixed systems would not be feasible due to the large area of deposition behind the north jetty and the difficulty in locating bypassing intakes. Further, they would require large capital costs to be effective, especially when so little of the channel shoaling would be remedied. Semimobile systems were also considered but the limited paved access roads and the sensitive nature of the park lands on Cumberland Island make these systems logistically difficult to support. The mobile systems proposed require no land access on Cumberland Island and do not require the high capital costs of construction and extended labor costs for maintaining a fixed or semimobile system.

Conclusions

23. The development of a comprehensive sand bypassing system for the St. Marys River entrance is not likely to provide significant reductions in the amounts of maintenance dredging required in the St. Marys River entrance channel. This conclusion is based on several sources of data that show the net transport rate of 90,000 cu yd/year to be a small portion of the gross transport rate of 1,000,000 cu yd/year. Sand bypassing is most effective when the net rate comprises a large portion of the gross rate. Bypassing effectively removes the net transport amounts from the channel maintenance dredging requirements.

24. Bypassing may be considered feasible based on other considerations and more limited expectations. Maintenance dredging will continue to be needed in the entrance channel as will disposal sites for this material. The material consists of clean sands that can be used for nourishing beaches. More detailed studies could indicate whether bypassing the material in the manner described herein would be more economical than allowing the material to enter the channel where it would likely be removed by conventional dredging equipment.

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